

WATER AND AGRICULTURE

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Abstract : The great agricultural plains conjure up visions of wealth and fertility. Paradoxically though, they are confronted with a serious problem : eroding soils and alteration of water quality. Today the best lands in the world are threatened by a diminution of natural fertility, a decrease in crops, floods, and mudslides. Moreover, changes in farming practice and land re-allocation (1966-1975) are also responsible for a plague entailing pollution of the environment, including soil and water and significant economical damages. What can be done in the medium term to avoid irreversible repercussions on environment and human health ?

Our work constitutes both a social debate on account of the socio-economic issues at stake, and the object of research of complex ecological rigour. It gives value to the multifunctionality of agrarian landscapes which equally are a reflection of the dysfunctions of agro-ecology : on the one hand, agricultural activities pollute the soil and water, and, on the other, agriculture is on the receiving end of urban and industrial pollution. The primary objectives are those of reconciling the productive necessities of competitive agriculture and the need for a better quality of life in tight symbiosis with « Nature ».

Keywords : Agriculture - Sustainable development - Erosion - Experimentation - Land use - Runoff - Water - Pollution - Parisian Basin - Europe.

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1 RURAL LANDSCAPES

Because they are so familiar to us, the great cultivated plains of Europe (cereals, maize, sugary beetroots, potatoes, etc), the synonyms of fertility and wealth, are considered as a well-known, surpriseless environment. They were long deemed as stable places, as opposed to tropical soils where the climate makes the soil susceptible to ablation and transport by water and wind (hydrologic erosion and wind erosion). Now, they are today at the core of serious problems concerning the environment and the development of agricultural land. Indeed, the acceleration of the erosion of the soils is obvious there, partly a consequence of the action of the climate, but mainly a consequence of deforestation, mechanization and farming intensification (Wicherek, 1994). These erosion problems, recognized years ago in the Great Plains and in North America grasslands, now affect the whole of the world's wealthiest lands, and can thus imperil the future of the planet's food balance. Was it to be expected ? The erosion which affected the Great American Plains in the 1920's and 30's, and which led to the Dust Bowl, was the cause of a long series of studies, the most famous ones being those by W.H. Wischmeier and D.D. Smith, in 1965. Unfortunately, these studies did not have any impact on farmers and politicians abroad. The European countries, in particular, did not feel concerned by the problems of soils and water degradation. How can we, today, explain the gravity of the situation and assess risks ? What solutions could we adopt without disrupting drastically the social and economic orientations ? (*Table 1*)

Water usage	1900	1940	1950	1960	1970	1980	1990	2000
Agriculture	525	893	1130	1550	1850	2290	3680 (68.9)	3250 (62.6)
Industry	37.2	12.4	178	330	540	710	973 (21.4)	1260 (24.7)
Domestic	16.1	36.3	52	82	130	200	300 (6.1)	441 (8.5)
Reservoirs	0.3	3.7	6.5	23	66	120	170 (3.6)	220 (4.2)

Table 1. Water world demand (km³ / year) according to the manners (agriculture : 62.6 %). (Numbers in brackets are percentages)

More generally, the majority of farming and fertile lands are to be found in the Northern hemisphere, together with the temperate climatic context allowing all types of cultures. The lands which are suitable for cultivation represent 22% of the area of earth (i.e. 60 times the area of France), and only half of them is currently cultivated. Productivity increases with the natural quality of the soils and climates, with the fashions and techniques used, as well as the addition of a given amount of fertilizers. The great agricultural domains are located in the plains in North-East America and their continuation in the Canadian meadows, the European meadows in the North West and East, as well as the plains and plateaux of Northern China.

Therefore, most of the agricultural potential in the world is to be found in the most industrialized countries : United States, Canada, European Union, Eastern Europe, IEC, Japan and China. Figure 1 allows us to give a rapid description of the agricultural situation in the most important industrialised countries, where the majority of the fertile agricultural lands in the world lie, and where the moderate climate in which all types of culture can thrive is to be found (*Figure 1*). Let us note that Europe, France included, possesses first rate potentialities and assets to play, worldwide, a predominant role in agriculture and food-processing industry, provided that some rules be respected in order to develop sustainable agriculture.

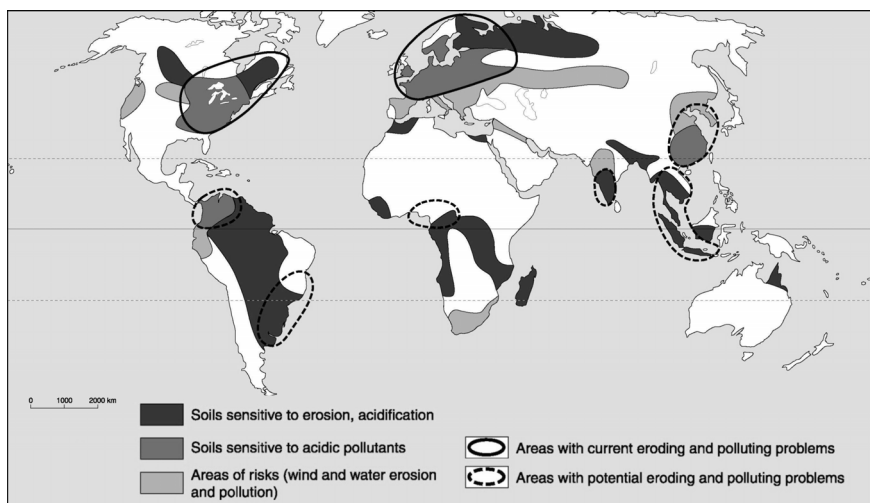


Figure 1. Worldwide repartition of agricultural areas sensitive to risks of water pollution and soil degradation (S. Wicherek, 1999).

These regions of great agriculture are characterised by a considerable production, and even an overproduction, accompanied by commercial difficulty. Hence the resort to the practice of leaving the land fallow constitute a tendency, which is sure to grow more accentuated in years to come. In fifteen years from now, this phenomenon could affect half of Europe's cultivated lands. We gather from these figures that these great domains are responsible for much of the world's alimentary future. Especially as the planet's population is growing rapidly, and could double over the next thirty years. The economical imbalance will then probably accentuate the gap between Northern countries and Southern ones, among other things impended by poorer agricultural lands and the climate. In Europe, as early as the Neolithic, men cut the trees in order to cultivate. Such practices intensified throughout the centuries. They took a new magnitude in

the 19th century to raise the volume of the agricultural production, partly because of the growing demographic pressure. The alteration of the soils accelerated around the 1960's, with the mutation of farming methods and the land re-allocation which were enhanced to affirm alimentary independence for most European countries, including France. In the past, generations of peasants tightly adjusted their systems of culture to the variants of the climate and soil. The rural society was in charge of the environment and the space in a very close manner. But the growing simplification of the farming methods and the transformation of this rural society have erased from the landscape the agricultural patchworks and the variety of the environment. The great fields and the few forest alternate today in the landscape, thus erasing the bioclimatic diversity. During decades, they were epitomised on the hillsides and in the hollow of the valleys by the aspect of fallow lands left vacant by the strong diminution of the "population of small cultivators". Then they were progressively neutralised by the wooding, whether spontaneous or voluntary. Today, villages and their belts of housing estates are established between the great forests and the cultivated lands. Such is the new rural landscape of the great European plains.

Now, this mutation had dramatic consequences on the way rain waters flow. Because of the absence of a permanent vegetal growth, instead of stagnating and seeping, waters began to run off, taking away with them the soil and its natural fertilisers, especially alluvion, clay and the organic materials which are also the binders of these fragile soils. So, in order to maintain the fertility of the soils, fertilizers were used which, carried away by the rain too, have polluted the rivers and the underground water areas. Pesticides and their surplus went also and contaminated the alimentary chains and thus had some impact on the quality of human health. The new techniques and methods of cultivation (dropping herbaceous, suppression of the hedges) have made the situation worse. The permanent passage of ever heavier machines has made the ground more compact, waterproof, for a depth of about 30 cm, thus enhancing the flowing of the superficial waters and making their infiltration towards the ground waters difficult. The consequences were the diminution of the natural fertility and crops, gullied fields, floods and mudslides. Such catastrophes were hardly known of a few decades ago, and partly account for the floods France has suffered over the past few years (Wicherek, 2000).

Sadly, the decision makers in Western Europe have not as yet taken these problems into sufficient consideration. It is unfortunate that there should be so few research laboratories, compared to North America, to work on this line of study with a sustainable view and in real conditions out in the field. Yet, at least twenty-five million hectares of arable land suffer from, or are

heavily threatened, by water erosion, which has globally intensified over several decades. It is in Mediterranean areas that the erosion of soils is most spectacular, because of the relief and the climate. Elsewhere, water erosion affects the lands where large-scale farming takes place, particularly the Northern part of the Paris Basin, the South-East of England, the silty and sandy loessic plains of Belgium, Germany, Poland on to Ukraine, and the Baltic plain as well (the Netherlands, Northern Germany, and a part of Denmark). As for wind erosion, it is limited to the littoral areas. Moreover, the Eastern Europe countries have to face the problems of acidic deposits and accumulation of heavy metals in the soil. It can be considered that a fourth of their cultivated lands is affected by these scourges. The excessive and irrational use of organic and chemical fertilizers leads to a heavy pollution of ground water and rivers (Wicherek, 2001). An another example of a bad management of water resources (irrigation and drainage) is the acceleration of the drying out in the North-Eastern parts of Hungary. The phenomenon can be observed North of Poznan, in the great Germano-Polish plain (Ryszkowski and Wicherek, 1997) and in some parts of Ukraine.

The annual cost of erosion in Western Europe has been estimated by De Ploey and coworkers (1990) as being of 1.6 billion euros for the 1990's and reaching more than 2 billion euros in 2002. This cost does not take into account the intrinsic value of the land, which is impossible to evaluate. Thus, the natural reconstitution of now eroded fertile soils in Europe would take several thousand years - provided it would take place under the action of a spontaneous vegetation, such as the oak-and-hornbeam groves and oak-and-beech groves that dominated the European area before the mediaeval deforestations. What is the situation in France ? Though the phenomenon of soil erosion is not as covered by the media as that of the 'acidic rains' or the forest fires, its implications are heavy with consequences, notably in the food-processing sector. In the early nineteen fifties, the total surface of land heavily damaged by water erosion, especially in the South-East of the country and in mountainous areas, has been estimated to 2.7 million hectares. Recent research, notably conducted by our centre, has revealed the importance of erosion in the Paris Basin : about five million hectares of land are now affected by water erosion. It is not uncommon to observe an erosion of up to thirty or fifty tons per hectare per year.

2 SOIL AND WATER DEGRADATION : PROCESSES AND CONSEQUENCES

Now, let us try to better understand what happens out in the field. The fertility of the soils depends on the relations existing between its

components : mineral elements (nitrogen, calcium, potassium, etc.), water, gas (carbon dioxide nitrogen, reducing gases, oxygen), organic matter, fauna. The soils least exposed to erosion are characterised by a great structural stability. This is caused by an assembly of solid particles by means of humic and clayey composites. This lumpy structure facilitates rainwater infiltration and slows down the tearing away of particles from the soil by runoff. Thus, in Europe, the most fragile soils, those that are the most subjected to erosion, comprise little humus (about 2%), little clay, and an important percentage of fine sands. The rains are the main cause of soil erosion : the rain drops and their kinetic energy tear away particles from the soil, which are carried along on a more or less important distance by surface runoff. The erosion is directly amplified by the slope of the field, which increases the speed of the flow, and by the compaction of the soils, which contributes to phenomena of runoff (Meybeck et al., 1998).

A closed vegetative cover (forests, lawns), including that of cultivated plants, protects the soils against erosion. The aerial parts of the plants and the ground-litter intercept the rain drops, disperse their kinetic energy, and slow down run-off. But when the soil has no vegetal screen, because it has been cleared for cultivation, or because it is between two crops after the harvest, it is weakened, especially when rains of sufficient intensity take place (more than fifteen millimetres of water per hour). This is what happens for arable lands on which cereal, maize, sugar beat or potato cultures take place.

A brutal change in the way of using the soils will take some time, something like a decade, in order for the quality of the waters and soils to improve. However, the pedological cover thickens slowly but constantly over a long period of time (the scale is that of centuries and millennia) from the parent rock. It now appears that the soil erodes much faster than it forms, which imposes a good management of the "soil-capital". To go further into the comprehension of the mechanisms of erosion, it is essential to lead fundamental research out in the field on the scale of the watershed. The gauging station at the point of outlet of the watershed enables us to make accurate measurements in a consistent way, in conditions of maximal homogeneity (climatic factors, water characteristics of the soil and their evolution, situation of the surface, runoff and sedimentary loss). This level is the only one for which a continuous monitoring (for example, the evolution of the surface situation and the formation of runoff during the rains) can really be considered. However, the station accounts neither for the diversity of the hillslope and the watershed, nor of the diversity of the local and regional situations. Therefore, a sufficient number of well-spread stations is necessary, but, most of all, it is essential to work on the scale of the watershed and the watershed complex. It is at this scale that one can, using a

network of measuring stations, study the influence of large-scale farming on the quality of waters. This spatial unit is elementary to study the deterioration of soils and waters, and for environmental studies at large. The recordings and instant quantitative measurements (made through the use of ultrasounds) and the qualitative measurements (made through automated analyses of liquid and solid flux) (Wicherek, 1991, 1995) at the extremity of watersheds are essential, completed by the climatic sensor parameters (intensity and quantity of rain), and the physical characteristics of the soils (moisture, for example). They enable us to understand the relations between the vegetal cover and the ways and techniques in which the soil is used (including the quantities of added chemical fertilizers). All these parameters are the basis for the modelling of the process of erosion.

3 TRANSFERS OF CHEMICALS FROM AGRICULTURAL LANDS

The soils subjected to that erosion see their natural fertility decrease and by way of consequence, the quality of ground and surface waters is altered by the adjunction of chemical fertilizers : nitrogen (N), potassium (K), phosphorus (P) (*Figure 2*). In Western Europe, five hundred kilograms of those fertilizers and three kilograms of pesticides are the average quantities spread in the fields per hectare and per year (Angélaume et al., 1994, 2002). Only three quarters of that is absorbed by the vegetation. Finding the direct link between the stages of development of the plants and their nutritive needs would enable to determine the best time for the injection of the fertilizers (to avoid surplus in the medium). Research on this subject is still in its early stages. The fauna (worms, etc.) and the micro-fauna (animals of a size inferior to 0.2 mm, for example the protozoa, and some nematodes), essential to the good balance of the soils and to their capacity in organic materials, are by now constantly dwindling away because of chemical fertilizers (Wicherek, 1995, 1999). The ratio of organic materials was of about 3% of the total weight twenty years ago. Now it is less than 2%, which corresponds to the critical threshold established by experiments.

Another way of water contamination from agricultural soils is the infiltration of chemicals that reach groundwater. The speed of percolation of polluting agents in the soils can reach up to tens of centimetres per year. There exists an interval of several years or even of several decades, between the first observation of the pollution of ground-water and the beginning of agrarian policies. That is why there may not be *a priori* more pollution now than around the 1970's, but there is a double effect of accumulation and latency.

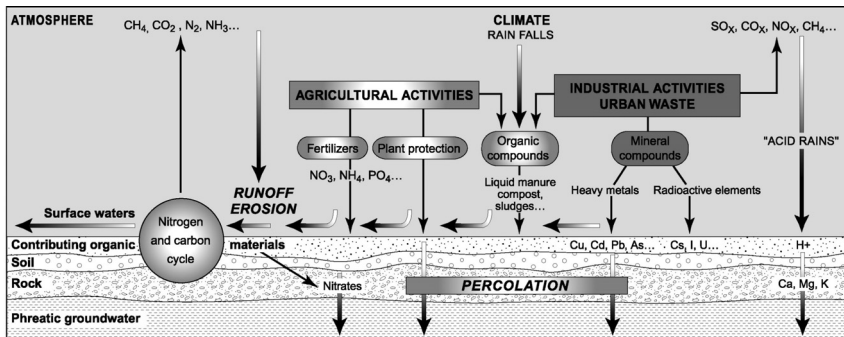


Figure 2. The main polluting agents that pass through the soils are the result of agricultural or industrial human activities: chemical fertilizers, pesticides, atmospheric polluting agents (acidic rains), heavy metals, urban waste, etc. All these polluting agents have an impact on the quality of the environment (soils, groundwater and rivers). The soil may be compared to a filter, or to a purifying system: when the waters go through it, their quality is altered and the natural fertility of the arable lands is reduced due to run-off. To maintain the fertility of the soils, chemical fertilizers must be used, which will in turn be carried away by the rain: the more important the intervention, the greater the risk of contamination of the food chains and thus of health hazards for humans (from Wicherek., 1994, 2000).

Consequently and additionally to alteration of soil quality, erosion soil processes have been also increasingly involved in the degradation of water quality. These processes combined with intensive mode of agricultural practices contribute to this degradation by nonpoint (diffuse) pollution. France has important water resources: available groundwater is estimated at 2.000 billions m^3 , and the 270.000 km of waterways and rivers represent a flow of 170 billions m^3 per year. 63% of the water used for human consumption comes from groundwater, and 37% from surface waters. One of the first processes implied in the degradation of water quality is the accelerated eutrophication of surface waters, due to high concentrations of nitrogen and phosphorus. This phenomenon is observed for 29% of French surface waters (Crouzet, 1999). Runoff waters appear to be key pollution vectors in the transfer of chemicals from crops to various receiving aquifer systems (rivers, lakes, ponds). This mainly occur following two ways of transfer: one, through surface runoff, which is present during storm events and often contains high levels of solid material, and second, through subsurface runoff which is more regular and generally drains mobile pollutants (De Coninck et al., 1991; Quilbé et al., 2002). Numerous examples have shown that, loss of phosphorus and nitrogen in eroding soils and their transfer through runoffs, lead unavoidably to eutrophication of

downstream surface waters (Sharpley et al., 1994 ; Dorioz et al., 1997). At the scale of two elementary agricultural watersheds (Erlon and Vierzy, Picardy, North Paris Basin) (*Figure 3*), several studies from our laboratory have shown, that variation of phosphorus and nitrogen concentrations in runoff collected at the point of outlet, were related to agricultural practices (crop rotation and fertilisation) performed on these intensively farmed areas (Angéliaume et al., 1994, 2002 ; Wicherek, 2001). However, the tendency since the 90's is an improvement of the general situation concerning eutrophication of surface waters, mainly due to the reduction of phosphorus concentrations in industrial and municipal loads. However, the problem still remains in agricultural regions due to nonpoint pollution. It is also estimated that 66% of nitrates present in surface water come from agricultural sources. High nitrate contents (> 250 mg/L) were found in subsurface runoff waters after nitrogen fertilization on the main part of the watershed which was cultured with low – covering crops (Quilbé et al., 2004). Some regions are particularly concerned, especially in Bretagne, where nitrates coming from soil application of hog manure induce eutrophication of coastal waters. In groundwater, the drinking standard for nitrates (50 mg/L nitrates, 11,3 mg N-NO₃/L) is frequently overtaken in regions of great agriculture or breeding, mainly in the north part of the territory. Based on the current evolution of nitrate contamination, it is estimated that, in 2030, Alsace groundwater (the most important reserve in Europe) could cease to be drinkable.

Concerning pesticides, datas from the Réseau National de Bassin (RNB) and the Réseau National des Eaux Souterraines (RNES) show that, in 2001, 39% of analysed rivers had a concentration above the drinking standards (0.1 µg/L for each substance and 0.5 µg/L for all pesticides). Pesticides are also present in groundwater : 36% of all the analysed waters and 27% of water used for drinking exceeded standards (Institut Français de l' Environnement - IFEN, 2003). The most commonly found substance is atrazine and its degradation products, although it has been forbidden for agricultural use in France in 2001 (of note for this substance, it is now officially forbidden in all Europe since October 2003).

Intensive agriculture is also implied, but to a less extend as compared to industrial and municipal loads, in contamination of soil and water by trace metal elements, since several metals are linked to the use of fertilizers and organic amendments such as sewage sludge (see below, next section). Trace metal elements contamination in water is difficult to estimate as data are still scattered and variable. As metals are likely to link with soil particles and sediments, the water contamination concerns especially the sediments and solid material of the great rivers, the highest levels being found in the estuaries. For example in the Seine estuary, the mean daily flow of mercury,

cadmium, copper, lead, and zinc is respectively 10, 50, 700, 700, 3000 kg per day. However, this contamination level has seriously decreased in the last years due to more severe standards for industrial loads. Intensive farming practices appear also to be involved in water pollution as on the 2 watersheds previously cited, we measured elevated total concentration of trace metal elements in non filtered surface runoff (highest values : 1,5 mg/L Cr, 1,7 mg/L Cu, 1,4 mg/L Ni, 0,9 mg/L Pb, 0,2 mg/L Cd) (Quilbé R., 2004).

It is important to note that this global poor quality of surface water and groundwater not only implies ecological impacts and risks for human health, but also has important economical consequences, due to the increasing cost of treatment processes needed to provide drinkable water, and to the loss of some uses of water (bathing or recreative activities for example). As a consequence, the average cost of drinkable water in France is estimated at 4 euros/m³ at the present time and includes 30% of state, regional and local taxes, 33% of drainage cost and 37% represent the real cost for water treatment (Wicherek, 2000).

4 AGRICULTURAL PRACTICE, EROSION AND WATER QUALITY : EXPERIMENTATION IN PARISIAN BASIN

4.1 Study sites presentation

The sites under study are located to the North of the Parisian Basin in the domain of the chalky plain of Picardie characterised by an undulating relief pattern, and a temperate oceanic climate with on average precipitation of 670 mm/yr. The major water courses, i.e the Serre, the Vulpion and the Oise, are tributaries of the Seine (*Figures 3a, 3b*). The site of Erlon is located on the North East of the right bank of the Serre. The Cultivated Elementary Watershed (CEW) is located in an area cut across by valleys, in the "soft waving horizons" of the Picardie plain, on extensively farmed lands. The slopes there are relatively distinct (48% of the slopes with a gradient from 2 to 5% and 39% of the slopes steeper than 5%) and have a concave form, which favours water collection (*Figure 3d*). Very few natural obstacles, like hedges, can be found. The soils which are predominantly made up of alluvia (20% of common alluvia and 80% of clay alluvia) and are particularly vulnerable to slaking (Fox, D.M. et al., 1998). The CEW is part of a complex system of watersheds which run on both sides of the Serre River and join up more or less freely with the alluvial plain. The size of these catchments ranges between 10 and 100 hectares (20 hectares for the experimental basin).

It should be emphasised that these CEWs show the same group characteristics as our experimental CEW (Veyret et Wicherek, 1992). They are characterised by dry thalwegs (with periodic flows), which are also quite short (less than a kilometre, causing a rapid evacuation of the water and erosion by concentrated run-off (Ouvry, 1990). Agricultural development on this experimental catchment dates back to the Neolithic period. Starting in second mid XXe century, it has gradually become intensive agriculture.

The flow of water, which can generate a rise in the water level, is the cause of the most spectacular forms of damage affecting the extensively farmed lands (agricultural lands, roads, villages) of the Parisian Basin (Wicherek, 2000). The ways in which the water flows away force us to take into account the morphological characteristics of the watersheds which give them different degrees of erosive risk (Boardman et al., 1990 ; Chisci & Morgan, 1986 ; Allison, 2002).

4.2 Measurements and results

From to experimental equipment (*Figures 3c, 3d*) installed downstream the main thalweg of the Erlon watershed, readings were done over 11 years (1991-2002). The first goal was to : generate quantified data synchronously, instantaneously ; analyze the physical and chemical quality of liquid and solid flows ; correlate the results obtained with different parameters, (i.g. rain intensity, soil humidity, etc.)

In this procedure geomorphologic and pedologic data, land uses (cultivation techniques and vegetation) and surface conditions are considered. We aim at obtaining accurate knowledge of degradation of cultivated soils (Wicherek 1991, 1993).

The downstream half of the Basin receives 30% more rain on average than the land upstream. In the study period the annual precipitation ranged between 577 mm and 1049 mm/yr. On the average, December was the wettest month (83 mm) as opposed to an average of 49 mm in March. Concerning the intensity of pluviometry, the maximum registered was 73 mm/hr on August.

Sound agricultural practices can help to decrease or slow down the process of runoff from the slopes. Unrelentingly unfavourable meteorological conditions (important pluviometry) throughout this period greatly contributed to the increase in the flooding. The impossibility for farmers to work the land in such unfavourable conditions must be accepted. The study thus allowed us to confirm a number of assumptions. In the winter season, the rain levels necessary to trigger runoff from a basin of 20 hectares vary considerably according to the land use ; in the case of a proportionally large amount of hard packed soil (harvested areas), a shower of 10 mm can lead to a runoff of

more than a hundred cubic metres (example of the event of 13/11/1993 : 125m^3 for 9.5 mm, or a runoff coefficient of 7%) ; in those cases where there is a lot of ploughing, and where winter cereals are grown, a 20 mm rainfall is not sufficient to trigger runoff. The intensity of winter rains, which are relatively low in comparison to those observed in the spring, do not play a major role in the triggering of runoff here, since on both occasions, the values are very close (36 mm/hr for 6 minutes and 9 mm/hr for 1 hour on 29/01/1995, as opposed to 5 and 3 mm/hr respectively on the 13/11/1993). Topography is an important factor : the water quickly collects on slopes because of surface depression with a gradient in the region of 2-5% and in hollows to be found in *thalwegs* which are grouped together. Alongside this, we can observe an increase of the time it takes for the water to spread out towards the water course, which is linked to the low gradient of the slopes of the alluvial plain (less than 2%). The 20 hectares CEW we studied represents a small catchment, yet far from being negligible if we consider the accumulation in the multiple similar elementary watersheds bordering the major water course. This allows the extrapolation of the results to other watersheds. The anthropic factor is primordial : the way the land is divided into sectors (5 plots of 4 hectares on average with various vegetal cover), the plant cover and the way the soil is used (particularly ploughing) influence the formation, the propagation and the volume of runoff and therefore the risk of flooding. Most of the produced biomass is cropped. A small part of organical matter is stocked in the ground. At present, organical matter in the soils decreases (2.4 %), reducing the fertility and the stability of the soils.

Concerning the runoff observed during spring and summer periods, the crops with high erosive risk are the followings in order of importance :

- . onions : the risk increases with frequent rain events ; an intensity less than 10mm/hr is sufficient to trigger the process (ex: 10/08/1999). A precipitations of 14.2 mm during 6.15 hr with a maximum intensity of 9 mm/hr, initiated a runoff of 150 000 litres, with a maximum rate of suspended matter (SM) reaching 19% by weight. If the event is repeated an intensity of 3mm/hr is sufficient to start the phenomenon (ex : 6/07/1999). The resumption a few hours after the first event has generated 380 000 litres, with a maximum rate of SM reaching 16% by weight. In certain cases runoff can exceed 200 g/l looking like mud flows with a maximum at 230 g/l (ex : 16/08/1999).

- . sugarbeets : an intensity of 12 mm/hr is sufficient to generate the first runoff and 3mm are necessary for resumption (ex : precipitations of 28/05/1992). Precipitations reaching 16,5 mm during 2 hours with a peak intensity of 12mm trigger an intensive runoff.

- . maize : an intensity ranging near 10mm/hr is sufficient to start the first erosion (ex : 3/06/2000 or 18/08/2000) and only 4 mm during one hour

permit the resumption. The solid matter carried along can reach the rate of 18, 6% (ex: 7/08/1995).

Other crops such as peas and French beans have not showed the triggering of runoff.

The best protection for soil by a vegetal cover proved to originate from cereals (winter corn and barley) which decrease the erosive process considerably, followed by corn and barley stubbles, also very efficient. It is also advisable to do away with ruts. Therefore vegetal cover at different phenological stages is involved directly in runoff control.

An other example is the 13/08/2000 event, with rainfalls reaching 46.4 mm during 3.30 hr and a maximum intensity of 20 mm/hr, wich generated runoff reaching 1 000 000 litres carrying only 2% of suspended matter (erosion). The ploughed soils appears to play a positive part but it was not possible to verify it in the period under study.

Concerning runoff in autumn and winter erosion reaching 1% is never reached during this period. This could be explained by adequate ploughing of the soil but during this period a low intensity of rainfalls was also noticeable with a maximum that never reached 9 mm/hr. The crops strongly implicated in the slowing down of runoff are corn and barley without stubbles. The maize sites under 39.8 mm rainfalls on 31/10/1998 during 19 hours with an intensity maximum of 8 mm/hr generated runoff downstream ; corn stubbles reduced considerably the process.

On the other hand in the sugarbeets sites on 10/11/1993, a rainfalls amount to 11 mm during 8 hours with maximum intensity at 2 mm/hr triggered runoff reaching 58 000 litres with a maximum rate of suspended matter (SM) only 7% by weight. The ploughed soils provided a very good protection against erosion at the beginning of the pluviometric periods but the effect decreases with time due to the smoothing of the surfaces.

In this case, the problem of soil must be looked at, as we can observe a direct relationship between plant cover, the runoff and erosion processes and the appearance of a rise in the water level, this affirmation is also valid for other periods. In the spring and in the summer, soil erosion represents a serious concern since suspended matter can reach 15% of the deposits. These losses can also involve nitrates and phytosanitary products, which raise the problem of the widespread pollution of surface water. Other studies are being carried out concerning this issue (Wicherek, 2000). It seems necessary to control the quantity of water involved in runoff in the winter season and the quality of these same amounts of runoff waters in the summer season. It seems that agricultural practices can play an important role in this form of management.

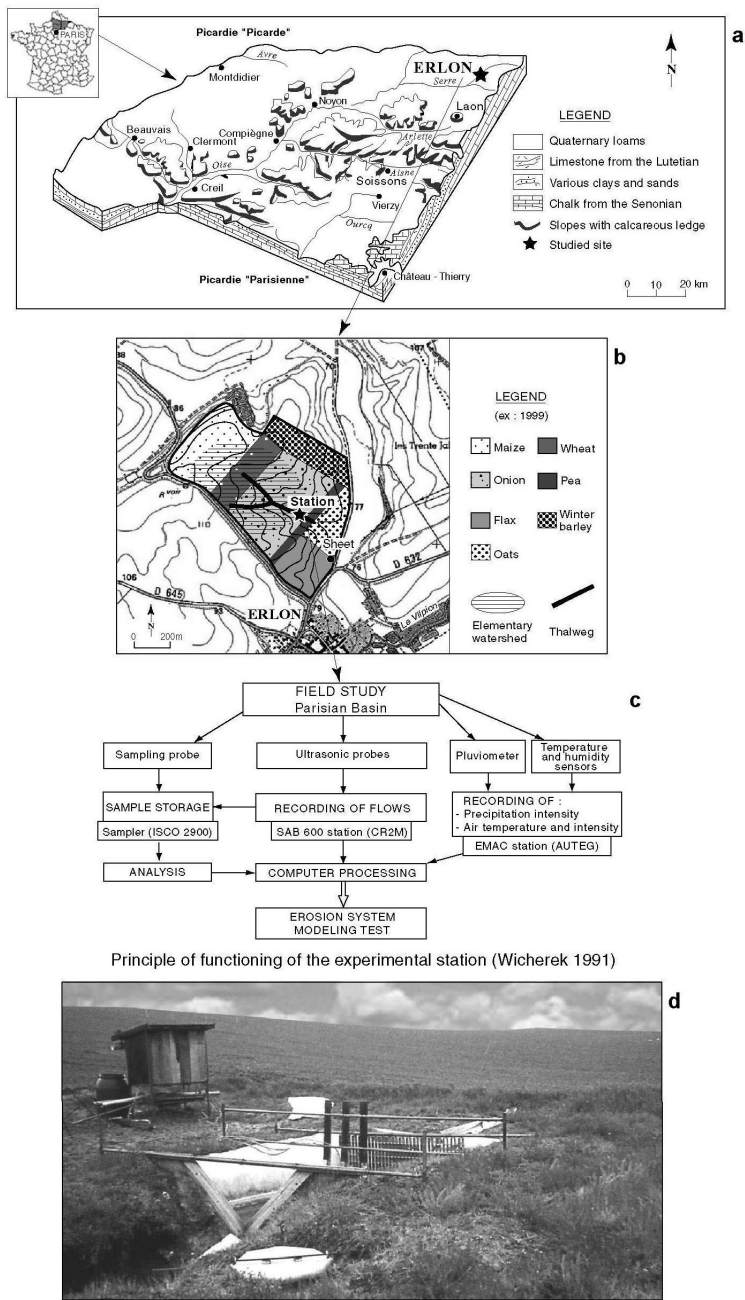


Figure 3. Location of the experimental site in the northern Parisian Basin, in the hill and plateau.

5 SOME SOLUTIONS TO PRESERVE THE QUALITY OF THE SOILS AND WATERS

The present knowledge on the deterioration of cultivated lands, acquired from the long experience in North America and over here, already enables us to suggest certain solutions so as to preserve the quality of the soils and waters (Billaud, 2002 ; Wicherek, 2000). Ploughing the land plays an essential part here ; on the one hand, this improves the soil's structure, as well as the infiltration, the roots' hold, and the output, but on the other hand, it accelerates mineralization, unbalance and deterioration of the soils. The improvement of the structures can be achieved through mineral enrichments (limestone, lime, etc.), organic enrichments (manure, compost, vegetal residue, green fertilizers) that are buried in the soil (mulching) and that directly protect the soil and improve its fertility and resistance to erosion. These enrichments are beginning to be implemented in France and Europe, but on a limited scale. This is due to a lack of information at a local level, made worse by the absence of precise regulations. According to our survey, the figure that is most commonly offered is of a loss of about 5% of the net agricultural income : beyond this threshold, the damages are heavily felt by the farmers ; the farmers are nevertheless ready to change their behaviour so as to bring those constantly growing risks under control. Cutting down the number of times the machines pass through the fields means changing the structure of the soils : it is necessary to introduce harrows under the ploughs so as to break the plough sole, making the machine lighter and at the same time to reduce effects of compaction. Minimal ploughing of the land (avoiding systematic annual ploughing) and direct sowing are encouraged in several European countries (Belgium, Germany). It has been recommended by several surveys led in the United States and in Western Europe (among which, our own results) to work the land perpendicularly to the slope, as well as to cultivate soils in the form of bands no wider than several hundred metres parallel to contour lines, which prevents the formation of run-off. Furthermore, the cultures must respect the different stages of the development of the plants (it is the case for hoed graminaceae and leguminosae). The stages of their development are spread out in time and space. For example : uphill, bare soils, or soils little covered by vegetation, allow the formation of run-off, while downhill, during the same period of time, the vegetation-covered soils prevent the water from flowing away. The distribution of the agricultural land in this perspective considerably reduces the shift of flux. Thus the constant presence of vegetative covers plays an essential part in the fight against erosion : indeed, ground litters or even cover plants (clover for example), are introduced into the cultures. It seems obvious that the destruction of the herbaceous plants, hedges, and embankments, makes flooding worse in several European areas ; preserving

them is thus very important and also partakes of the preservation of biodiversity. Slopes contribute to the development of erosion, their inclination being more important than their length, unless furrows appear. The topographical position plays a major part: the bottoms of slopes are often saturated and eroded faster than the summits of hillslopes. The classical schemes of lay-out must thus be revised. The main effect of surface state of the soils on run-off - particularly that of ground litters, biological activities and crusting-over - must make us rethink the notions of deep work, superficial work, and work in clods to facilitate infiltration.

Let us hope that modern man shall tackle the 'true' problems of the Earth ; that he shall learn to manage better the use of his nourishing earth, and to develop the knowledge and technology which are necessary to the conservation of soils and water for the future generations.

ACKNOWLEDGEMENTS

The author thanks warmly B. Julien-Laferrière, computer engineer in BioGeo, and G. Chêne, field investigator on watersheds, for their efficient collaboration.

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